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ON THE CHANGE OF HEAT TRANSFER INTENSITY THROUGH A DIELECTRIC IN AN ELECTRIC FIELD

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ON THE CHANGE OF HEAT TRANSFER INTENSITY THROUGH A DIELECTRIC IN AN ELECTRIC FIELD

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ABSTRACT. As a result of experiments it is discovered that the rate of heat exchange of a metal bar with the outside medium through a dielectric decreases when a permanent external electric field is switched on. A physical explanation is given.

We will examine the metallic rod placed in a dielectric and continuously /113*
heated to a temperature t_1. The heat generated in this rod is dissipated through the dielectric into the surrounding medium. Let the temperature of the surrounding medium be τ. The temperature in the dielectric drops from t_1 at the surface of its contact with the rod to t_2 at the boundary with the surrounding medium. We will assume that this drop takes place in accordance with the straight line law. It is obvious that when the rod is continuously heated, heat equilibrium will be established after a certain time. This equilibrium is characterized by a constant temperature t_2. How does this temperature and the conditions of heat exchange in the system change if, with all other conditions being equal, we apply a constant electric field with voltage E to the dielectric?

It is clear that polarization will take place in the dielectric. If the dielectric is polar, then each of its dipoles forms a pair of forces which will tend to turn the dipole into the direction of E. In the case of a non-uniform field the pondermotive force in the dielectric, in relation to unit volume, will be, as we know,

$$f = \frac{\varepsilon - 1}{8\pi} \nabla E^2.$$

This force tends to shift the dielectric into the region of the greatest voltage of the field.

It might be assumed that if the voltage of the field and the temperature in the metallic rod are maximal, then the intensity of the heat transfer through the dielectric will be reduced, since the applied field will tend to lower the amplitude of heat oscillations of the polarized atoms and molecules, and also of the constant dipoles. For this reason the temperature t_2 should be reduced to some extent. For the purpose of testing this assumption we conducted experiments with high-voltage cables according to the diagram illustrated in Figure 1.

* Numbers in the margin indicate pagination in the foreign text.

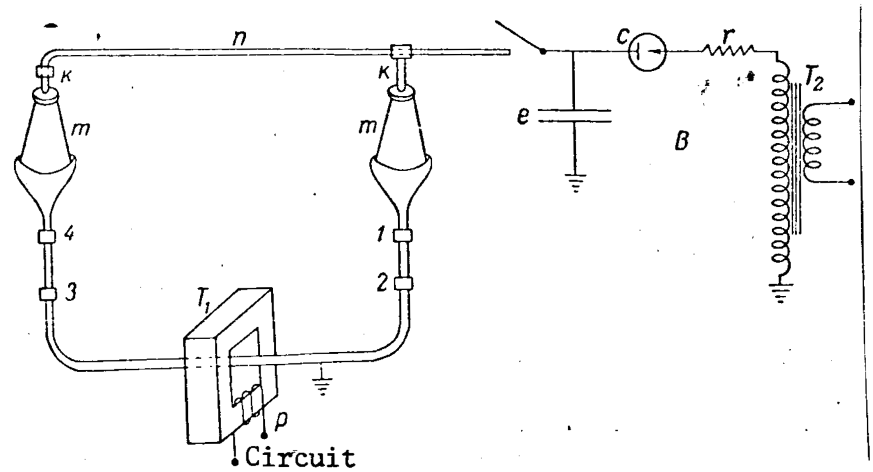

Figure 1. Diagram of Experiments for Establishing the Effect of Reduced Heat Transfer Intensity During the Application of an Electric Field.

The insulation of the cable, which was 120 mm in thickness, consisted of a slightly polar dielectric, i.e. cable paper, permeated with an oil-colophony compound. The conductor core consisted of wound copper wires. A segment of the cable 6 m in length had a bare lead coating. The ends of the copper wire (k) were connected (bolted) to soldered copper terminals by a connecting cable (n), which was also made of copper wires of the same cross-section. We thus formed a closed contour (loop). The lead coating of the cable remained disconnected and insulated from the cable by the porcelain couplings (m). This /114
coating was grounded during the experiments. The cable was placed in the iron core of a special load transformer (T_1), which had one primary winding (P), which was connected to the electrical circuit by an autotransformer. In this arrangement the closed contour, consisting of the core of the cable and the connecting cable, represented the secondary winding of the transformer (T_1). For the purpose of heating this core, large load currents of low voltage were passed through it. Since the lead coating of the cable, as we mentioned before, was open, these currents did not flow through it. The force of the load current was measured by Dietz forceps and was maintained constant (constant source of cable heating) during the experiment.

Heat equilibrium, i.e. the state where the quantity of heat liberated in the core is equal to the heat dissipated by the coating of the cable, was established after about five hours. After this time the temperature of the lead coating became constant. We placed heat resistances in the form of collars, which densely compressed the coating of the cable (1, 2, 3, 4), in several places on the covering on both sides of the load transformer. We used a galvanometer, which was connected to the heat resistances by a bridge circuit, to record the temperature. As a check we placed several mercury thermometers on the lead coating.

After the heat equilibrium was established, where the temperature of the coating of the cable was constant for one hour (about 6 hours after the start of the test) for a constant load current, a constant voltage of 100 kv was delivered from the rectifier B (see Figure 1) to the core of the cable without switching off the load current. The rectifier consists of a high-voltage transformer T_2, limiting resistance r, kenotron c and condenser e with a capacitance of 0.1 μf for smoothing out the voltage fluctuations during single half period rectification.

If the electric field had no effect on the heat conductance of the permeated cable paper, the temperature of the covering, as before, would remain constant. Systematic measurements, however, showed that when the constant voltage of 100 kv relative to the grounded lead covering was applied to the core of the cable, the latter cooled noticeably. The curves of the varia- /115 tion of the temperature of the covering are shown in Figure 2. These curves were constructed for two values of low current, 330 and 280 a. The temperatures of the coating t_2 thus established were 35.8 and 30.8°C, respectively. We see from these that for a load current of 330 amps the temperature dropped by 4°C, and for 280 a, it dropped 2°C after 10 min in both cases.

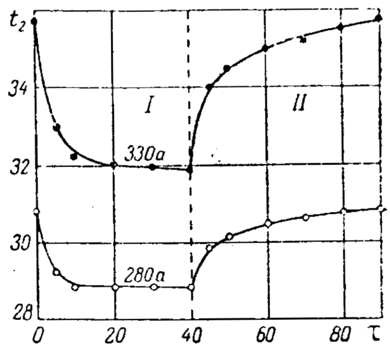

Figure 2. Curves of Variation in Time (minutes) of Temperature (°C) of the Lead Coating of the Cable after Switching On (I) and after Switching Off (II) Constant Voltage 100 kv.

After a period of 40 minutes the high voltage was switched off while the load current, as earlier, was maintained. The temperature of the coating of the cable again increased to the initial temperature.

We might point out in conclusion that it appears, probably, to be advisable to consider the effect of the change in the intensity of heat transfer during transmissions of electrical energy by constant voltage through underground or underwater cables. After some cooling of the lead coating, a reduction in the intensity of the dissipation of that from the core results in its further heating.

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